HUMAN-COMPUTER INTERFACE INCORPORATING PERSONAL AND APPLICATION DOMAINS

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PRIORITY CLAIM

This application claims the benefit of U.S. Provisional Application 60/202,448, filed on 05/06/2000, incorporated herein by reference, and U.S. Patent Application 09/649,853, filed on 8/29/2000, incorporated herein by reference.

BACKGROUND OF THE INVENTION

This invention relates to the field of human-computer interfaces, specifically those relating to haptics, multidimensional displays and navigation, interaction with multidimensional environments and objects, and methods of intuitively interfacing therewith.

Computing technology has seen a many-fold increase in capability in recent years. Processors work at ever higher rates; memories are ever larger and always faster; mass storage is larger and cheaper every year. Computers now are essential elements in many aspects of life, and are often used to present three dimensional worlds to users, in everything from games to scientific visualization.

The interface between the user and the computer has not seen the same rate of change. Screen windows, keyboard, monitor, and mouse are the standard, and have seen little change since their introduction. Many computers are purchased with great study as to processor speed, memory size, and disk space. Often, little thought is given to the human-computer interface, although most of the user's experience with the computer will be dominated by the interface

(rarely does a user spend significant time waiting for a computer to calculate, while every interaction must use the human-computer interface).

As computers continue to increase in capability, the human-computer interface will become increasingly important. The effective bandwidth of communication with the user will not be sufficient using only the traditional mouse and keyboard for input and monitor and speakers for output. More capable interface support will be desired to accommodate more complex and demanding applications. For example, six degree of freedom input devices, force and tactile feedback devices, three dimensional sound, and stereo or holographic displays can improve the human-computer interface.

As these new interface capabilities become available, new interface methods are needed to fully utilize the new modes of human-computer communication enabled. Preferably, such new methods can build on interface methods learned by users in real-world situations and in two-dimensional computer interfaces. Specifically, users have become accustomed to two-dimensional computer interfaces, with control panels, menus, and buttons. Users are also accustomed to three-dimensional interfaces in real-world situations, visual and tactile depth perception aid in finding and manipulating such controls. For example, the controls of a car radio are always in some understandable relationship to the usual position of the driver. Such simplistic relationship can be undesirable in a three-dimensional computer environment, however, where the user can desire that controls be available during three-dimensional navigation free of the requirement of experiencing the environment through a windshield.

Fuller realization of the entertainment and productivity benefits possible from computer technology requires more improved interfaces. Accordingly, there is a need for improved human-computer interfaces that offer more intuitive navigation and control of the computer.

SUMMARY OF THE INVENTION

The present invention provides a human-computer interface. The interface includes provision of an application domain, for example corresponding to a three-dimensional application. The user

is allowed to navigate and interact with the application domain. The interface also includes a personal domain, offering the user controls and interaction distinct from the application domain. The separation into two domains allows the most suitable interface methods in each: for example, three-dimensional navigation in the application domain, and two- or three-dimensional controls in the personal domain. Transitions between the application domain and the personal domain are under control of the user, and the transition method is substantially independent of the navigation in the application domain. For example, the user can fly through a three-dimensional application domain, and always move to the personal domain by moving a cursor near one extreme of the display.

The arrangement of domains, the method of controlling transitions between domains, and the method of communicating when a transition occurs can all have significant effect on the overall effectiveness of the human-computer interface. Accordingly, the present invention comprises various arrangements of personal domains and application domains, corresponding to various desirable human-computer interface characteristics. The present invention further comprises various techniques for allowing a user to control transition between domains, and for communicating to the user when a transition occurs.

Advantages and novel features will become apparent to those skilled in the art upon examination of the following description or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

DESCRIPTION OF THE FIGURES

The accompanying drawings, which are incorporated into and form part of the specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

Figure 1 is an illustration of a computer display representing an application domain and a personal domain.

Figure 2(a,b) is an illustration of a computer display representing an application domain and a personal domain, showing the display when each domain is the active domain.

Figure 3(a,b,c) is an illustration of a computer display representing an application domain and a personal domain, showing the display when each domain is the active domain and showing a transition from the application domain as the active domain to the personal domain as the active domain.

Figure 4(a,b,c,d) is an illustration of a computer display representing an application domain and a plurality of personal domains, showing the display when each domain is the active domain.

Figure 5 is an illustration of the correspondence of one personal domain with three application domains.

Figure 6 is an illustration of a three-dimensional application domain and three personal domains.

Figure 7 is a flow diagram of an example implementation of the present invention.

Figure 8 is a schematic diagram of an example implementation of the present invention.

Figure 9 is an illustration of an application domain and a personal domain, as desired to be presented to a user.

Figure 10 is an illustration of the range of motion of the input device in the two domains.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a human-computer interface. The interface includes provision of two distinct domains, and detection of transitions between the two. The interface provides an application domain, for example corresponding to a three-dimensional application. The user is allowed to navigate and interact with the application when the application domain is active. The interface also provides a personal domain, offering the user controls and interaction distinct from the application domain. The separation into two domains allows the most suitable interface methods in each: for example, navigation in the application domain, and controls in the personal domain. Transitions between the application domain and the personal domain are under control of the user, and the transition method can be substantially independent of the navigation in the

application domain. For example, the user can fly through a three-dimensional application domain, and always move to the personal domain by moving a cursor near one extreme of the display or one extreme of the application domain.

The arrangement of domains, the method of controlling transitions between domains, and the method of communicating when a transition occurs can all have significant effect on the overall effectiveness of the human-computer interface. Accordingly, the present invention comprises various arrangements of personal domains and application domains, corresponding to various desirable human-computer interface characteristics. The present invention further comprises various techniques for allowing a user to control transition between domains, and for communicating to the user when a transition occurs.

THE APPLICATION DOMAIN

The application domain corresponds to an application, and provides interaction with the user according to the interface characteristics appropriate to the application. For example, if the application includes a space navigable in three dimensions, the application domain can provide display of the three-dimensional space, and interaction comprising navigation in three dimensions. Interaction in the application domain includes detection of user input to designate the personal domain as the active domain. Active domain transitions are discussed below. Designation of the personal domain as the active domain can be independent of control of the application so that the user always has an intuitive path back to the personal domain. Reliance on ready and consistent access to the personal domain can improve the effectiveness of the human-computer interface. Designation of the personal domain as the active domain can be in a consistent manner across multiple applications, allowing a user to rely on the availability and interface characteristics if the personal domain instead of learning new interface characteristics for each application. Further, the interaction in the application domain can be consistent across multiple applications, allowing a user to work with multiple applications without requiring adaptation to different application interfaces.

THE PERSONAL DOMAIN

The personal domain corresponds to a personal interaction environment, and can include interaction with characteristics of the application and interaction external to the application. For example, the personal domain can include controls over aspects of the application, including navigation in a three-dimensional application space. It can also include interaction such as communications (e.g., mail, inter-computer communications) and data operations (e.g., printing, file organization and operations). The interaction environment of the personal domain can be distinct from the application domain, since the personal domain can focus on personal interaction needs rather than interaction required by the application. The interaction environment of the personal domain can also be substantially consistent across many application domains, allowing the user to learn a single interface paradigm useful in many applications.

The personal domain includes detection of the user designating the application domain as the active domain. Transitions from the personal domain to the application domain can be different from transitions from the application domain to the personal domain, without confusion to the user since the interaction environments are distinct. The personal domain can also include detection of transitions to other personal domains, and to multiple application domains. A user can transition from an application domain to a personal domain. While in the personal domain, the user can interact with the computer according to a familiar personal interaction environment. The user can transition from the personal domain back to the application domain, or to other personal domains tailored to specific interaction needs (e.g., interactions related to computer communications can be grouped in a single personal domain). The user can also transition from the personal domain to other application domains.

TRANSITIONS BETWEEN DOMAINS

Provision of natural, intuitive transitions between active domains can be important to the overall effectiveness of the human-computer interface. Each transition preferably is accessible to the user via intuitive controls, for example with computer metaphors of physical world

interactions. Each transition can also include feedback to the user so that the user is always certain which domain is active.

Control of a cursor in multidimensional spaces can provide intuitive transition controls. An active domain can include a boundary between it and another domain. The user can effect a transition to the other domain by causing the cursor to traverse the boundary. Once in the new domain, the boundary might be reset to correspond to the interaction environment of the new domain. The boundary can be visible, such as a line or region shown on the display. For example, the application domain can use the majority of a display for application purposes, and reserve a portion at the bottom of the display for a boundary to a personal domain. Moving the cursor into that lower portion causes a transition to the personal domain. The personal domain can now use the entire display for personal domain interaction, and can use a different portion of the display, or a different transition control, to indicate transition back to the application domain. Further, the correspondence of input device with computer interaction can be different in different domains. For example, a three-dimensional interface device can be active in the application domain and a two dimensional device in the personal domain. As another example, the cursor motion, speed, and resulting navigation can be in different relation to the input device in different domains.

The boundary can also be invisible, such as by corresponding to a consistent portion of the domain or a consistent motion of a cursor control input device. For example, moving a cursor off the bottom edge of a display in the application domain can cause a transition to a personal domain. As another example, if the cursor is controllable in three dimensions, moving the cursor toward the user can cause a transition to a personal domain (i.e., the user "pulls out" of the application domain). The transition can also be relative to the motion of an input device. For example, moving a cursor control device to an extreme of its range of motion can cause a transition between domains (e.g., the user can get to the personal domain by moving the input device all the way back, or by making a specific set of motions with the input device).

The occurrence of a transition between domains can be communicated to the user. The characteristics of the display presented to the user can be distinct among the different domains. The display of the new domain can displace that of the former domain in a perceptible manner, for example by sliding in front of the former display, pushing the former display off, or rotating the former display out of view. The imminence of a transition can also be communicated to the user by providing force feedback to a user input device. The force feedback, for example, can be a click (as though the user dragged a pen across a crack in a surface) or a bump (as though the user was moving between physical spaces with a raised boundary).

The imminence of a transition can also be communicated to the user, and unplanned transitions avoided, by applying a force resisting the motion that would cause a transition. For example, if boundary traversal causes a transition, a force substantially opposing motion toward the boundary can be applied to a user input device. The occurrence of such a transition can be communicated by reducing the resistive force when the domain transition occurs, providing the user with haptic feedback of a sensation of popping through a barrier between domains.

EXAMPLE OF INTERFACING WITH A PERSONAL DOMAIN AND AN APPLICATION DOMAIN

Figure 1 is an illustration of a computer display representing an application domain and a personal domain. The application domain is represented to the user as an application portion 101 of the display 100. The personal domain is represented to the user as a personal portion 102 of the display 100. The user controls which domain is currently active, and interfaces with the computer according to the interface characteristics of the currently active domain. For example, the user can control the position of a cursor, and designate the active domain by moving the cursor to the portion of the display corresponding to the domain desired to be the active domain.

Moving the cursor to a defined region of the application portion of the display (in the figure moving the cursor to the bottom of the application portion) can switch the active domain to be the personal domain. While in the personal domain, the user can be presented with an interface having characteristics distinct from those of the application domain. For example, the personal

domain can offer interface characteristics applicable to a wide variety of applications, providing the user a consistent and intuitive way to access a consistent set of system interface tools. The personal domain can offer interface tools affecting the application domain, and can offer interface tools affecting other than the application domain. For example, the personal domain can offer tools affecting the scale or content of the application domain, and can also offer tools allowing communication with other applications, other users, or other features of the computer.

Moving the cursor to a defined region of the personal portion (the top in the figure) can switch the active domain to be the application domain. The relationship between the application domain and the personal domain can be substantially independent of interaction in the application domain, allowing the user a consistent and intuitive way to access the personal domain. For example, the user can navigate a three-dimensional application domain with few restrictions, flying, teleporting, zooming in or out, moving objects, etc. At all times in the application domain, the controls of the personal domain are accessible in the same manner, providing easy access to the interface characteristics of the personal domain.

The user can control transitions by movement of a cursor (visible or invisible). An input device can also have its range of motion mapped such that a transition between domains is indicated by moving the device to a defined region of the range of motion. For example, a joystick as an input device can have the extreme back portion of its range of motion correspond to a transition to the personal domain, and the extreme forward portion of its range of motion correspond to a transition to the application domain. The transition definition can be dependent on which domain is currently active.

The interface can also provide feedback to allow the user to manage transitions across the boundary between the application domain and the personal domain. A force fed back to an appropriate input device, directed substantially away from the boundary, can provide the user a haptic indication of the boundary. The force can decrease perceptibly as the transition occurs, providing the user a sensation of pushing through a boundary and entering the newly active domain. The haptic feedback can allow effective designation of the active domain without

requiring careful visual management of the cursor by the user, and can help prevent inadvertent active domain transitions.

EXAMPLE OF CHANGING DISPLAY AS THE ACTIVE DOMAIN CHANGES

Figure 2(a,b) is an illustration of a computer display. In figure 2a the application domain is the active domain. Most of the display 200 is devoted to the application portion 201; the user can be effectively immersed in the application. The user can still, however, access the personal domain in an intuitive and consistent manner. The personal domain is represented in Figure 2a as a small portion 202 of the display; it can be invisible as long as the user can reach it in an intuitive manner. The user can switch the active domain to be the personal domain by moving the cursor toward the bottom of the application portion of the display, whether into the small portion as shown in Figure 2a or to the bottom if the personal portion is not visible. Figure 2b shows the display changed as the personal domain becomes the active domain. The application portion 202 consumes a larger portion of the display 200. The user can interact with the personal domain and make use of the larger portion of the display now available for the personal domain.

EXAMPLE OF THREE-DIMENSIONAL DISPLAY CHANGE AS THE ACTIVE DOMAIN CHANGES

Figure 3(a,b,c) is an illustration of a computer display with the active domain the application domain (Figure 3a), the personal domain (Figure 3c), and a transition between the two (Figure 3b). In Figure 3a, the application domain is the active domain. The entire display 300 can be used for the application, and the user can be immersed in the interface characteristics of the application. Moving the cursor to a defined region of the display, the right edge in the figure, indicates a transition to the personal domain as the active domain. Figure 3b shows the display change as the interface accommodates the transition from the application domain to the personal domain. The display reflects an animation of the application domain moving off the display and the personal domain moving into its place. The figure shows the transition as an illusion of the user turning the head from looking at the application domain to the side where the personal domain resides. Making the transition from the application domain to the personal domain

substantially independent of navigation and control in the application domain provide the user an interface that allows interaction with the application while keeping the interface of the personal domain always accessible just by "looking" to the side (moving the cursor to the right). The user can move back to the application domain by simply moving back to the left of the personal domain display.

EXAMPLE OF MULTIPLE PERSONAL DOMAINS, WITH THREE-DIMENSIONAL INTERFACE EXPERIENCE

Figure 4(a,b,c,d) is an illustration of a computer display associated with an application domain and three personal domains. The application domain occupies the majority of the display 400 when the application domain is the active domain. The interface provides the user with three personal domains, one below the application domain and one at either side of the application domain (shown virtually in the figure extending from the display). The personal domains at the sides can be accessible via the sides of the application domain, the sides of the lower personal domain, or both, depending on the interface experience desired. The user can interact with the application domain while it is active, and always have access to interface tools in the three personal domains by merely causing transition to one of them as active. For example, the user can interact with objects in a three-dimensional sculpting application. Moving the cursor to the left can provide the user access to that personal domain, perhaps providing access to interface tools that customize the characteristics of the sculpting application. Moving the cursor to the right when in that personal domain moves the user back to the application domain. Moving the cursor to the bottom of the application domain causes that personal domain to become active, perhaps providing access to other applications or other users. Moving the cursor back up returns the user to the application domain. Moving the cursor to the right provides access to that personal domain, perhaps providing access to computer system tools (e.g., printers and file systems).

EXAMPLE OF PERSONAL DOMAIN INDEPENDENT OF APPLICATION DOMAINS

The interface can provide the user with personal domain interface characteristics consistent across diverse applications. Each application can have its own interface characteristics, as

dictated by the needs of the application. Diverse applications, however, can provide similar methods for transitioning to the personal domain. Once in the personal domain, the user can be presented with familiar interface characteristics.

Figure 5 is an illustration of a single personal domain offering transitions to multiple (three in the figure) application domains. Each application 501, 502, 503 transitions to the personal domain 504 by moving the cursor to the right edge of the display. Once in the personal domain 504, the user can interact according to the personal domain interface characteristics. The personal domain provides transitions to three different application domains 501, 502, 503; the user transitions to one by moving the cursor to that region of the personal domain.

EXAMPLE OF PERSONAL DOMAINS IN CONNECTION WITH A THREE-DIMENSIONAL NAVIGABLE SPACE

Figure 6 is an illustration of three personal domains 602, 603, 604 and an application domain 601. Application domain 601 corresponds to an application space navigable in three dimensions: app-x, app-y, and app-z. When the application domain is the active domain, the user can navigate therein, using almost the full range of the three dimensional space or three dimensional input device. Moving a cursor to a portion of the application space nearest the user (or smallest range of app-z), for example by moving the cursor in the app-z direction or by moving the input device toward the corresponding extreme of its range of motion, can cause a transition to the first personal domain 602 as the active domain. A resistive force can be applied as the cursor nears the transition region to provide more positive user control of the transition, and then reduced when the transition occurs to provide more positive communication of the transition.

When the first personal domain 602 is the active domain, the user can be presented with an interaction environment corresponding to the first personal domain. The interaction environment can comprise two dimensions, corresponding to just the plane of the boundary in the figure. Alternatively, the interaction environment can comprise three dimensions, for example comprising three dimensional buttons or controls and three-dimensional haptic feedback.

Transitions to other domains can be similar to as discussed for the application to first personal domain transition, except that the first personal domain provides access to two other personal domains as well as back to the application domain. Moving to the far portion of the first personal domain can cause a transition back to the application domain, optionally including force feedback as discussed before. Moving to the far left of the first personal domain can cause a transition to the second personal domain. Moving to the far right of the first personal domain can cause a transition to the third personal domain. Once in the second or third personal domains, the user can again use almost the full range of the three dimensional space for interaction in the domain (similar to the discussion for the first personal space). Moving back across the corresponding edge can cause a transition back to the first personal domain.

Other mappings of domains and domain boundaries can be used, including boundaries beyond those possible with conventional three dimensional spaces. For example, the second and third personal domains in Figure 6 can be directly linked via a domain boundary at their lower edges, not possible with a physical three dimensions. The mapping shown in Figure 6 does, however, present the user with an intuitive, physical world sensation: the personal domains are intuitively in front of the application domain, and once in the first personal domain the second and third domains are at the user's sides. Force feedback can enhance the physical world sensation: the user can interact in the application domain, then pop through the front wall into the personal domain, interact there, then pop back into the application domain or the other personal domains.

EXAMPLE IMPLEMENTATION

A human-computer interface incorporating the present invention can be implemented with computer programming tools and techniques known to those skilled in the art. As an example, Figure 7 is a flow diagram of one suitable implementation, accommodating multiple domains, with cursor/boundary transitions between domains, and with force feedback near the boundaries.

The interface comprises display and interaction according to the active domain 701. As discussed above, the display and interaction can be distinct between domains. The user input is

monitored to detect when the cursor exceeds a boundary between the present active domain and another domain 702. If it has, then any force feedback relevant to the boundary is reduced 703, the active domain changed to the new domain 704, and the display and interaction replaced with those corresponding to the newly active domain 701. If it has not, then a determination is made whether the cursor is nearing an inter-domain boundary 705. If it is, then an appropriate feedback force is applied 706. Since the cursor is not past the boundary, the display and interaction are still according to the presently active domain 701.

Another illustration of an implementation of the present invention is shown in Figure 8. An application domain function ADF effects a display and interaction according to the application domain. An active domain controller ADC monitors for transitions indicated by the user to other domains, for example by cursor motion. When the ADC detects such a transition, control is transferred to the other domain, in the figure to personal domain function PDF. The PDF communicates the transition to the user, for example by reducing force feedback and by moving the display of the personal domain in place of the display of the application domain. The PDF then provides display and interface according to the personal domain. The ADC still monitors for transitions indicated by the user to other domains, for example by cursor motion. When the ADC detects such a transition, control is transferred to the function implementing the other domain. The figure shows only two domains; the number of domains and mapping between domains can be as needed to achieve the desired user interface characteristics.

EXAMPLE DOMAIN AND INPUT DEVICE MAPPING

Figure 9 is an illustration of an application domain and a personal domain, as desired to be presented to a user. The user can interact with the domains using an input device moveable in three dimensions: x-device, y-device, and z-device. The input device can have limited range of motion, however. For efficient interaction with either domain, it can be desirable that a majority of the range of motion of the input device be dedicated to the active domain.

The range of motion of the input device can be mapped based on the active domain. As an example, Figure 10 is an illustration of the range of motion of the input device in the two domains. On the left, the rear portion of the range of motion (x-device, y-device, and z-device space) is mapped to interactions with the application domain. A smaller front portion of the space is mapped to a personal transition portion. The user thus has most of the input device's range of motion available for interaction with the application domain. The user can indicate a transition to a personal domain by moving the input device into the personal transition portion of the space. On the right is an illustration of the mapping of the space after transition to a personal domain. The front portion of the space, mapped to interaction with the personal space, is larger than on the left, allowing more of the input device range of motion to be used in personal space interactions. A smaller rear portion of the space is mapped to indicate transitions to an application domain. The figure shows a rectangular space with a planar boundary; the space and boundaries can have various shapes depending on the input device characteristics and the specific user interaction experience desired.

The display can also be configured to enhance the interaction according to each domain. As an example, objects in the personal domain can be displayed at one size when the user is interacting according to the application domain, and at another, larger size when the user is interacting with the personal domain. As another example, objects in the personal domain can be displayed with differing visual intensities depending on which domain is active. As another example, objects in the personal domain can be displayed as transparent or semitransparent when the user is interacting with the application domain, and as solid when the user is interacting with the personal domain.

The particular sizes and equipment discussed above are cited merely to illustrate particular embodiments of the invention. It is contemplated that the use of the invention may involve components having different sizes and characteristics. It is intended that the scope of the invention be defined by the claims appended hereto.